

# Isometric strength vs. functional mobility and their relationship with risk of falls in community-dwelling older adults: a prospective study

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## SUBJECT AREAS

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*functional assessment; geriatric; elderly; physical performance; muscle strength; sarcopenia*

## Abstract

**Background:** Falls are a major concern for older adults and their care givers. The Timed Up and Go (TUG) test is extensively used to identify individuals at risk of falling, but less is known about the validity of simple isometric strength measures for this purpose. We aimed to assess the potential of isometric strength measures and the different modalities of the TUG test to detect individuals at risk of falling.

**Methods:** Twenty-four community-dwelling older adults ( $\geq 65$  years, 19 females,  $88 \pm 7$  years) performed three variations of the TUG test (standard, cognitive, motor) and three isometric strength tests (handgrip, knee extension and hip flexion) at baseline and at several time points (every  $\sim 6$  weeks) during a 13-month follow-up. Linear mixed model analyses were then performed to examine differences between those who sustained  $\geq 1$  fall during the follow-up and those who did not.

**Results:** Fallers had a worse performance in all TUG variations and a lower strength in all tests than non-fallers in non-adjusted analyses ( $p < 0.05$ ). However, when adjusting for baseline variables (age, gender, body mass index, and previous history of falls), only differences in handgrip and knee extension isometric strength measures remained significant ( $p = 0.019$  and  $p = 0.042$ , respectively). Isometric strength measures related to changes in TUG performance both at baseline and during the follow-up ( $p < 0.05$ ).

**Conclusions:** Isometric strength measures has potential to serve as a simple tool to detect individuals at risk of falling as compared to functional mobility measures (i.e. TUG test).

## Background

Falls are a major concern for older adults and everyone involved. An estimated 30% of adults over 65 years of age fall at least once per year increasing to 50% for those over 80 years of age [1, 2]. One third of these falls lead to mild-to-severe injuries and in many cases require hospitalization, thereby imposing a substantial burden on health and social services [3, 4]. Moreover, falls are the largest cause of restricted activity among older adults [4], which further contributes to their functional decline [5]. Thus, optimizing screening tools to identify individuals at risk of falls should be a priority [6].

Apart from extrinsic risk factors (e.g., slippery floor, poor lighting), a number of intrinsic factors have been associated to a higher risk of falls [7]. These person-specific factors include non-modifiable characteristics such as age or gender; but also amenable factors such as physical performance [7]. The assessment of physical performance (e.g., balance, muscle strength, or functional ability) is therefore recommended to screen individuals at high risk of falls [6].

The timed up and go (TUG) test is one of the most popular tool for assessment of physical fitness - specifically, of functional mobility - in older adults [8]. It consists of the participant getting up from a chair, walking three meters, turning at a designated spot, returning to the seat and sitting down (TUG-cognitive: while counting backward; TUG-Motor: holding a filled cup). This test is recommended as an assessment of sarcopenia [9] and as a screening tool for fall risk by the American and British Geriatrics Societies [10]. However, despite its popularity and some evidence supporting its usefulness [11, 12], different systematic reviews and meta-analyses have questioned its actual validity [13–15]. Muscle strength, an important determinant of physical fitness which deteriorates with aging [16, 17], can be easily assessed during isometric voluntary contractions by means of portable dynamometers [18, 19]. Evidence suggests that fallers present an impaired isometric strength in multiple muscle groups, compared to non-fallers [20–23]. In this context, the main purpose of this study was to analyze the validity of isometric strength vs functional mobility (different modalities of TUG test) measures for the identification of individuals at risk of falls.

## Material And Methods

# Participants and study design

This study followed a prospective design and complies with the STROBE checklist for Observational Studies. The study was conducted in agreement with the Declaration of Helsinki and approved by the regional Ethics Committees. All participants (recruited via a local physician) signed an informed consent form after having the procedures explained.

Inclusion criteria were community-dwelling older adults  $\geq 65$  years of age, living independently, and having no pets (data stems from a larger study for monitoring physical activity using ambient sensors, hence “no pets” and “single living”). Level of independence and cognition was assessed at

baseline using the Katz score [24] and Montreal Cognitive Assessment (MOCA) [25]. Depending on the participants' ability (0 - unable to perform without help, 0.5 - able with little help, 1- no help needed) to independently perform six different basic activities of daily living (i.e., eating, transferring from bed to chair, walking, using the toilet, bathing, and dressing), summing to a final score for each individual, ranging from 0 to 6 [24]. Participants' functional ability, isometric strength and incidence of falls were assessed at baseline and continuously every ~6 weeks during a 13-month follow-up. All assessments were conducted at the participants' home, by the same researcher, and at approximately the same time of the day. The assessments were randomized for each visit.

## Assessment of physical performance

### Functional ability

Functional ability was assessed using the TUG-standard, TUG-cognitive and TUG-motor tests [26].

During TUG standard, participants stood up from a chair, walked 3 meters, turned around, walked back to the chair, and sat down. During TUG cognitive, participants performed the TUG standard task while counting backwards from a randomly selected number between 20 and 100. During TUG motor, participants performed the same TUG standard task while carrying a full cup of water. The time (in seconds) required to complete each test was recorded using a stopwatch.

### Isometric strength

Maximal voluntary isometric handgrip strength was assessed with a digital hand dynamometer (Jamar Plus+, Sammons Preston Rolyan, Chicago, USA) following available guidelines [18]. Briefly, participants remained seated with their elbow flexed at 90° and the forearm and wrist in a neutral position resting on the arms of the chair. They performed three maximal trials with each hand and the highest value recorded during the six trials was retained for analysis. Maximal voluntary isometric strength of the hip flexors and knee extensors was measured with a hand-held dynamometer (Lafayette 01165, Lafayette Instrument Company, Lafayette, USA) according to the methodology described elsewhere [19]. For both muscle groups, participants were seated with both hips and knees flexed at 90°. For the assessment of hip flexors, the dynamometer was placed on the anterior part of the thigh proximal to the knee joint, whereas for the knee extensors the dynamometer was placed on

the anterior aspect of the shank, proximal to the ankle joint. Following the same protocol as with handgrip strength, participants performed three maximal trials for each muscle group and side, and the highest value of each muscle group was retained for analyses.

## Assessment of falls

According to the American and British Geriatrics Society falls prevention guidelines [10], a fall was defined as an unexpected event in which the participant came to rest on the ground, floor or lower level without known loss of consciousness. Previous history of falls was assessed through personal interviews with the participants and their relatives. During the follow-up, nursing students visited the seniors once or twice a week in order to record the incidence of falls by means of questionnaires. Falls that occurred as a result of events such as dizziness, heart attack or syncope were not included.

Participants who sustained  $\geq 1$  fall during the follow-up were considered 'fallers'.

## Statistical analysis

Differences between groups (i.e., fallers vs non-fallers) at baseline were assessed using Student's unpaired t-tests. To account for missing data (<25% at each time point, and with no missing data in baseline measures), differences between groups during the follow-up (presented together with 95% confidence intervals [CI]) were determined using linear-mixed modelling. The physical tests (i.e., functional ability or isometric strength) were considered as the dependent variable, group (i.e., fallers vs non-fallers) was set as a fixed factor, and subject was added as a random intercept. Analyses were adjusted for age, gender, body mass index, and previous falls history as fixed factors. The relationships between the different tests at baseline were assessed using linear regression analyses (Pearson's correlation coefficient). Relationship of changes in isometric strength during the follow-up to changes in functional ability was tested using linear mixed modelling, setting both variables as fixed factors. All analyses were performed using the statistical software (SPSS version 23.0, IBM, Armonk) under a significance level of  $\alpha = 0.05$ .

## Declaration of sources of funding

This funding source played no role in the design, execution, analysis and interpretation of data, or

writing of the study

## Results

A total of 24 community-dwelling older adults were included in the study (*Table 1*). Participants had their physical performance assessed at baseline and  $45 \pm 8$ ,  $88 \pm 10$ ,  $131 \pm 18$ ,  $177 \pm 19$ ,  $224 \pm 23$ ,  $273 \pm 17$ ,  $316 \pm 19$ ,  $359 \pm 20$  and  $390 \pm 12$  days later. Twelve participants fell at least once during the follow-up, resulting in a total of 20 falls. Of these, 4 falls were due to stumbling, and the remaining ones had no specified cause. Two participants died during the study at ~5 and ~9 months during the follow-up, and thus could only be assessed 4 and 6 times, respectively. Both of them had a previous history of falls, and did also sustain a fall during the follow-up.

Fallers did not differ from non-fallers in gender or Katz score, but were older, had lower cognitive scores, and higher body mass index (*Table 1*). Significant differences were found at baseline between fallers and non-fallers for TUG standard and TUG motor, but not for TUG cognitive. Inter-group differences were also observed for handgrip and knee strength, but not for hip strength (*Table 1*). Non-adjusted analyses showed a decline in all TUG modalities and lower strength in all tests during the follow-up for fallers compared to non-fallers (*Figure 1, Table 2*). Isometric strength measures of knee extension and handgrip remained significantly different between fallers and non-fallers when adjusting for potential confounding factors (i.e., age, gender, body mass index, and previous falls history). By contrast, no between-group differences were found for isometric hip flexion nor for any of the TUG variations in adjusted analyses, although a non-significant trend was observed for both TUG standard and cognitive (*Table 2*).

Secondary analyses showed that all isometric strength measures significantly correlated to each other at baseline and were also associated to at least one TUG modality (*Table 3*). Similarly, the longitudinal changes in the different isometric strength measures were also associated to changes in performance of at least one TUG modality (*Table 4*).

## Discussion

The main finding here is that isometric strength measures of different muscle groups (i.e., knee extensors and handgrip) significantly differentiated fallers from non-fallers during a 13-month follow-

up regardless of potential confounding factors such as age, gender, body mass index, and previous history of falls. By contrast, although fallers did also present a worse performance than non-fallers in all TUG test modalities (i.e., standard, count and cup), these differences disappeared when adjusting for confounding factors, which supports isometric strength as a sensitive screening measure.

The TUG test is one of the widely used test for the identification of individuals at risk of falling [10] and its validity has been studied by some. Shumway-Cook et al. [11] observed that the TUG test had a sensitivity and specificity of 87% to detect individuals prone to falls. However, in line with our findings, more recent evidence has called into question the validity of this tool [13-15]. Some authors suggested that the inclusion of dual/cognitive TUG tasks (e.g., counting back) might increase its validity for this purpose [26]. Accordingly, the inclusion of additional TUG tasks increased its accuracy in identifying pre-frail individuals in some studies [27]. However, other authors found similar sensitivity and specificity when comparing the three (standard, cognitive, motor) TUG modalities [11]. Although the cognitive status of fallers was significantly lower than non-fallers at baseline, none of the TUG modality performances here (including those with cognitive tasks) could discern fallers from non-fallers in adjusted analyses. Thus, the evidence supporting the validity of the TUG test with or without dual-tasks for the identification of individuals at risk of falls is at least inconclusive.

On the other hand, the present study supports the validity of isometric strength measures as a screening tool to detect individuals at risk of falling. Previous studies have shown that fallers present with an impaired function of lower limb muscles - as measured by different tests such as the chair stand test, jumping, or leg press strength - compared to non-fallers [21, 28]. Isometric strength measures such as those implemented here have also been previously related to falls risk in older adults. Pijnappels et al. [21] observed that individuals who fell after gait perturbations presented the lowest isometric knee extension strength. In addition, Menant et al. [20] observed that low isometric knee extension strength was related to different health-related outcomes in the elderly (including balance, functional mobility and falls). Isometric knee extension strength has also appeared as a better prognostic factor than other measures such as muscle mass alone or a combined score (includes both muscle mass and strength/functional performance) as proposed by the European

Working Group on Sarcopenia in Older People (EWGSOP) [20]. Thus assessment of isometric lower-limb strength might be a simple and valid screening tool [20].

Interestingly, our results also show that - apart from knee extension strength - handgrip strength differentiates between fallers and non-fallers. The assessment of handgrip strength is arguably the most widely used [29] as well as the simplest option for the evaluation of isometric strength in older adults. This test is recommended by the EWGSOP for the assessment of sarcopenia [9], and has proven to be a valid prognostic factor of different health-related outcomes including low intrinsic capacity, hospitalization risk, or overall mortality [30–32]. Evidence from meta analyses support the validity of handgrip strength for the prediction of age-related declines in cognition, mobility, functional status and mortality in community-dwelling older people [33]. Previous studies have also reported differences between fallers and non-fallers in terms of handgrip strength [21–23]. Combined, these results do support the use of handgrip strength assessments as a simple screening tool in clinical practice, although its combination with other measures (e.g., functional mobility tests) could enhance predictive accuracy [34].

We also observed that isometric strength measures across different muscle groups were not only related between themselves, but were overall related to performance on the TUG test at baseline and during the follow-up. Bohannon [35] already suggested that handgrip and lower limb isometric strength measures could represent a common construct, as reflected by the strong correlation found between the two markers. Other authors have also reported an association between lower-limb strength—including isometric knee extension—and handgrip strength [21]. Moreover, Alonso et al. [36] recently reported that handgrip strength was not only related to knee extension strength, but also to TUG performance and dynamic balance in older adults. Similarly, handgrip strength has been reported to be correlated with ambulatory capacity in frail older adults [37]. Thus, these findings suggest an association between isometric strength and functional mobility, which would further support the clinical relevance of assessing and enhancing muscle strength in the elderly [17].

Limitations of this study include the small sample size and the short follow-up time. Moreover, not all participants could perform the scheduled tests at all time points due to various reasons (e.g., death,



health issues). Hence, linear mixed modelling was used to account for missing data [38]. The present findings might not necessarily be applicable to other populations with different characteristics, such as older adults with comorbidities or those living in nursing homes. However, the major strength of this study is its prospective nature and the fact of having assessed different modalities of the TUG test and different measures of isometric strength continuously throughout the follow-up period.

## Conclusions

The present study shows that isometric strength measures of different muscle groups (i.e., knee extensors and handgrip) can differentiate between fallers and non-fallers among older adults, remaining these differences significant even when adjusting for potential confounding factors such as age, gender, body mass index, and previous history of falls. Fallers did also present a worse performance on all modalities of the TUG test, but no differences were observed for adjusted analyses. There was a significant correlation between the different isometric strength measures and the changes in TUG performance. Isometric strength measures (particularly knee extension and handgrip) have potential to serve as a simple and easy tool to detect individuals at risk of falling as compared to functional mobility measures (i.e., TUG test).

## Declarations

## Ethical approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the canton of Bern, Switzerland (KEK-ID: 2016-00406) and the Ethics Committee Northwestern and Central Switzerland EKNZ. All participants signed an informed consent form after having the procedures explained.

*Data availability.* All relevant data supporting the findings are available upon request.

## Consent for publication

Not applicable.

## Availability of data and materials

Data will be made available upon request.

## Competing interests

The authors declare that they have no competing interests.

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## Author's contributions

Study concept and design: NAM, HS, NS, TN, PU.

Acquisition of data: HS, NS, BR, TN, PU

Analysis and interpretation of data: PLV and NAM.

Drafting the manuscript: PLV and NAM.

Critical revision of the manuscript for important intellectual content: All authors.

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## Tables

Table 1. Baseline characteristics of study participants.

Variable	All (n=24)	Fallers (n=12)	Non-fallers (n=12)	p-value
Gender (n, % female)	19 (79%)	9 (75%)	10 (83%)	0.615
Age (years)	88 ± 7	91 ± 8	86 ± 6	0.055
Body mass index (kg·m <sup>-2</sup> )	24.4 ± 3.2	23.3 ± 3.5	25.5 ± 2.6	0.083
Katz ADL score [max = 6]	5.7 ± 0.7	5.5 ± 0.9	5.8 ± 0.4	0.259
MOCA score [max 30]	20.9 ± 5.5	18.5 ± 5.7	22.8 ± 2.4	0.033
Handgrip strength (kg)	20.9 ± 5.6	17.7 ± 4.9	24.2 ± 4.3	0.002
Hip flexion strength (kg)	15.5 ± 5.2	14.3 ± 3.8	16.8 ± 6.2	0.248
Knee extension strength (kg)	13.2 ± 4.4	10.8 ± 3.4	15.6 ± 4.2	0.006
TUG standard (s)	12.1 ± 7.5	15.2 ± 8.3	8.9 ± 5.1	0.038
TUG cognitive (s)	14.9 ± 15.7	20.0 ± 20.7	9.7 ± 5.4	0.110
TUG motor (s)	12.7 ± 5.6	15.0 ± 4.6	10.5 ± 5.6	0.049

Values expressed as mean ± SD (unless otherwise stated). The p-values refer to the differences between fallers and non-fallers. Significant p-values are highlighted in bold. Abbreviations: ADL, activities of daily living; BMI, body mass index; MOCA, Montreal Cognitive Assessment; TUG, timed up and go test.

Table 2. Differences in physical performance tests between fallers and non-fallers during the 13-month follow-up.

Test	Crude difference (95 %CI)	Adjusted difference (95 %CI)
Handgrip strength (kg)	-7.01 (-10.72, -3.31) p = 0.001	-5.74 (-10.41, -1.08) p = 0.019
Hip flexion strength (kg)	-4.22 (-8.00, -0.43) p = 0.031	-2.72 (-6.98, 1.54) p = 0.196
Knee extension strength (kg)	-7.11 (-11.00, -3.22) p = 0.001	-4.92 (-9.62, -0.21) p = 0.042
TUG standard (s)	9.23 (1.63, 16.82) p = 0.020	7.23 (-0.71, 15.16) p = 0.072
TUG cognitive (s)	13.30 (2.93, 23.66) p = 0.014	9.62 (-1.43, 20.67) p = 0.084
TUG motor (s)	8.53 (1.73, 15.32) p = 0.016	4.56 (-2.92, 12.03) p = 0.216

Data (estimate [95% confidence intervals] and p-value) represent the difference between groups (i.e., fallers vs non-fallers) during the follow-up. Significant p-values are highlighted in bold. \*Adjusted for gender, age, body mass index, and previous history of falls.

Table 3. Relationships between isometric strength and functional mobility at baseline.

	Hip	Knee	TUG standard	TUG count	TUG cup
Handgrip strength	r=0.63 p=0.001	r=0.76 p<0.001	r=0.64 p=0.001	r=0.51 p=0.011	r=0.60 p=0.002
Hip flexion strength	-	r=0.79 p<0.001	r=-0.19 p=0.385	r=-0.02 p=0.942	r=0.42 p=0.045
Knee extension strength	-	-	r=0.49 p=0.015	r=0.26 p=0.226	r=0.71 p<0.001
TUG standard	-	-	-	r=0.92 p<0.001	r=0.93 p<0.001
TUG cognitive	-	-	-	-	r=0.94 p<0.001



Data are shown as Pearson's correlation coefficient (r) together with p-values. Significant p-values are highlighted in bold.

Table 4. Relationship between changes in isometric strength and functional mobility during the follow-up.

	Hip flexion strength (kg)	Knee extension strength (kg)	TUG standard (s)	TUG count (s)	TUG cup (s)
Handgrip strength (kg)	0.17 (0.11, 0.234) <b>p&lt;0.001</b>	0.19 (0.13, 0.24) p<0.001	-0.04 (-0.06, 0.01) p=0.011	0.00 (-0.02, 0.01), p=0.635	-0.09 (-2690, 2690) p=0.684
Hip flexion strength (kg)	-	0.48 (0.41, 0.56), <b>p&lt;0.001</b>	-0.10 (0.15, -0.06) p<0.001	-0.05 (-0.08, -0.02) p<0.001	-0.13 (-0.18, -0.07) p<0.001
Knee extension strength (kg)	-	-	-0.15 (-0.19, -0.11), <b>p&lt;0.001</b>	-0.03 (-0.05, 0.00) p=0.033	-0.12 (-0.52, 0.28) p=0.146
TUG standard (s)	-	-	-	0.75 (0.74, 0.77) p<0.001	0.56 (0.52, 0.60) p<0.001
TUG cognitive (s)	-	-	-	-	0.62 (0.58, 0.66) p<0.001

Data (estimate [95% confidence intervals] and p-value) represent how a unit change in the variables displayed in rows affect the change of the variables displayed in columns. Significant p-values are highlighted in bold.

## Figures

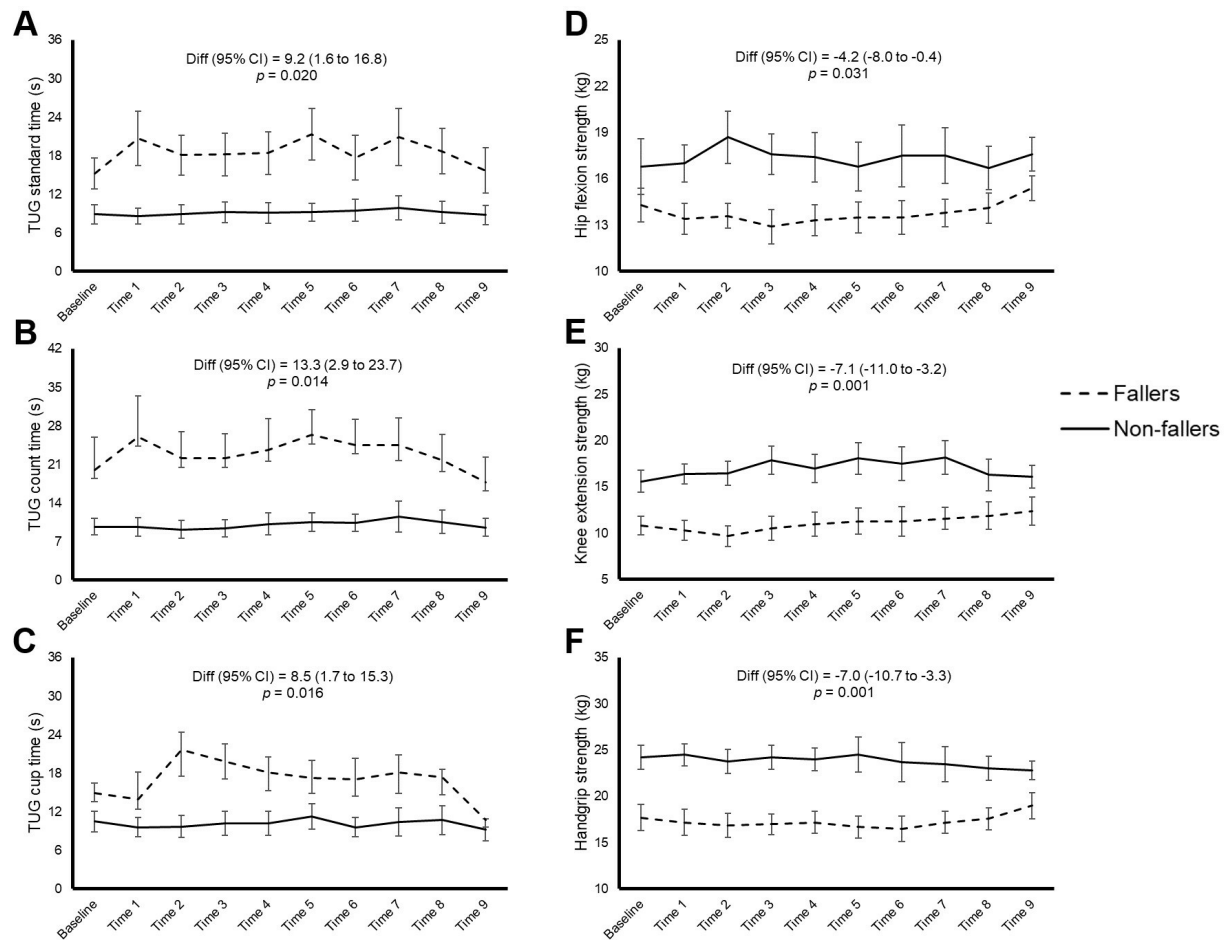


Figure 1

Functional mobility (A-C) and isometric strength (D-F) results in fallers and non-fallers during the 13-month follow-up. Multiple imputation was performed to create the figures, as there were missing data (<25%) at some time points. The crude difference (diff, expressed along with 95% confidence intervals [CI]) corresponds to the average difference between groups, and was computed using linear mixed model analysis with no data imputation. Significant differences between groups were found for all tests.